SEASONAL OCCURRENCE OF *BRACHYMERIA INTERMEDIA* (HYMENOPTERA: CHALCIDIDAE), A PARASITOID OF THE GYPSY MOTH, *LYMANTRIA DISPAR* (LEPIDOPTERA: LYMANTRIIDAE), IN WESTERN MASSACHUSETTS

V. Kerguelen and R. T. Cardé[1]

Department of Entomology, Fernald Hall, University of Massachusetts, Amherst, Massachusetts 01003

Abstract.—To document the life history of *Brachymeria intermedia* in the U.S., we monitored the presence of reproductively active wasps in the field using trap hosts over an 8-week time period in early summer. The overall level of recovery of wasps was low (8% peak parasitism on average), yet, all parasitism occurred within one week. Reproductively active *B. intermedia* seemed to be fairly synchronized with gypsy moth pupation, suggesting that they might be univoltine and monophagous. However, we cannot conclude unequivocally that *B. intermedia* is monophagous, because these wasps appear to disperse readily to other habitats where their behavior is unknown.

Key words: Host finding.

Brachymeria intermedia (Nees) was introduced from Europe to the United States as a potential biological control agent against the gypsy moth, *Lymantria dispar* L. It was released repeatedly from 1908 through 1963 (Hoy, 1976; Clausen, 1978), but its establishment was not confirmed until 1966 (Leonard, 1966). Dowden (1935) reported that in Europe *B. intermedia* completes one generation on the gypsy moth in late spring. A second generation develops on other lepidopteran hosts in late summer. However, owing to differences in climate between the Mediterranean areas where wasps were collected and New England, and therefore to differences in the phenology of the gypsy moth, it was suggested then that the life cycle of *B. intermedia* might differ if the wasp established in the United States. Howard and Fiske (1911) hypothesized that adult wasps lived long enough to allow a single generation life cycle with the gypsy moth as a sole host. Conversely, Dowden (1935) suggested that American *B. intermedia* might have a first generation on alternate hosts in the spring. Then, a second generation would develop on the gypsy moth (with a possible late third generation on alternate hosts.)

Thirty years after the establishment of *B. intermedia,* the life cycle of the wasp in the United States is still unclear. Recoveries of wasps from species other than the gypsy moth have been rare (Prokopy, 1968; Leonard, 1975), yet many species are accepted as hosts in the laboratory (Dowden, 1935; Minot and Leonard, 1976; Rotheray et al., 1984; Dindo, 1990; Drost and Cardé, 1992a). Whether *B. intermedia* parasitizes other species before gypsy moth pupae are available in the field remains unknown. Although it was verified that females overwinter as adults (Waldvogel and

---

[1] Current address: Department of Entomology, University of California, Riverside CA 92521.

Brown, 1978; Schaefer, 1993), we do not know when wasps become active in the spring. In this study, we monitored the presence of reproductively active *B. intermedia* in the field, before, when, and after wild gypsy moth pupae were present.

MATERIALS AND METHODS

Study sites: The study was conducted in three sites, Ludlow, Amherst and Montague, Massachusetts. These sites were selected for their high densities of gypsy moth the preceding years. The sites in Ludlow and Amherst were dominated by oaks (*Quercus rubra* L., *Q. alba* L. and *Q. prinus* L.). The site in Montague was a mixed stand of birch (*Betula populifolia* Marshall), oaks (*Q. rubra, Q. ilicifolia* Wangenheim), pines (*Pinus rigida* Miller) and willows (*Populus tremuloides* Michaux).

Monitoring: We monitored the presence of actively reproductive wasps by exposing trap hosts continuously in the field from June 2, to July 21, 1994 in Ludlow (8 weeks) and June 6 to July 21, 1994 in Amherst and Montague (7 weeks). Trap hosts are nonparasitized hosts reared in the laboratory, placed in the field and recovered after short intervals of time to be checked for parasitism (Van Driesche et al., 1991). At each site, one cage holding 10 two to five day-old male gypsy moth pupae, reared from eggs on artificial diet in the laboratory (Bell et al., 1981), was stapled on 10 trees, 3 to 5 meters apart (oak in Ludlow and Amherst and birch in Montague). Thus, 100 pupae were exposed at each site. Cages were made of 7 mm wire mesh and placed ca. 2 m above ground level on the south side of trees. Pupae were renewed weekly and subsequently reared in the laboratory at 24 ± 1°C, 60–70% relative humidity with a 16 L:8 D light cycle. They were checked daily for emergence of moths or *B. intermedia.* Deaths due to predation in the field and to unexplained causes were also recorded. Mortality rates were computed as the marginal rates of attack, i.e., the rates of mortality due to each mortality agent in the absence of other contemporaneous agents (Buonaccorsi and Elkinton, 1990; Elkinton et al., 1992). Mortality due to predators was computed as the observed death rate. Mortality due to *B. intermedia* and unexplained causes was computed as the marginal rates of attack for two contemporaneous indiscriminate parasitoids (with $c = 0.5$).

RESULTS

The outcome of the rearing of pupae exposed in Ludlow, Amherst and Montague is presented in Fig. 1a, 1b and 1c, respectively. Overall, most pupae escaped parasitism and survived to the adult stage at all three sites (69, 49 and 77% average adult emergence, respectively), with little variation over the course of the experiment. Parasitism by *B. intermedia* was low at all sites and occurred only during one week: 15% parasitism (12 wasps recovered) at Ludlow on week 3 (mid-June), 1% parasitism (1 wasp recovered) at Amherst on week 5 (early July) and 9% parasitism (8 wasps recovered) at Montague on week 5. Predators (beetles, hemipterans, and ants) had a low impact (8, 35 and 3% average predation, respectively), although a high predation rate (77% on average), mainly attributed to ants, was observed the last three weeks of study at Amherst. Larger predators including mice, were excluded by the cages. Mortality due to undermined factors averaged 24, 39 and 19%, respectively.
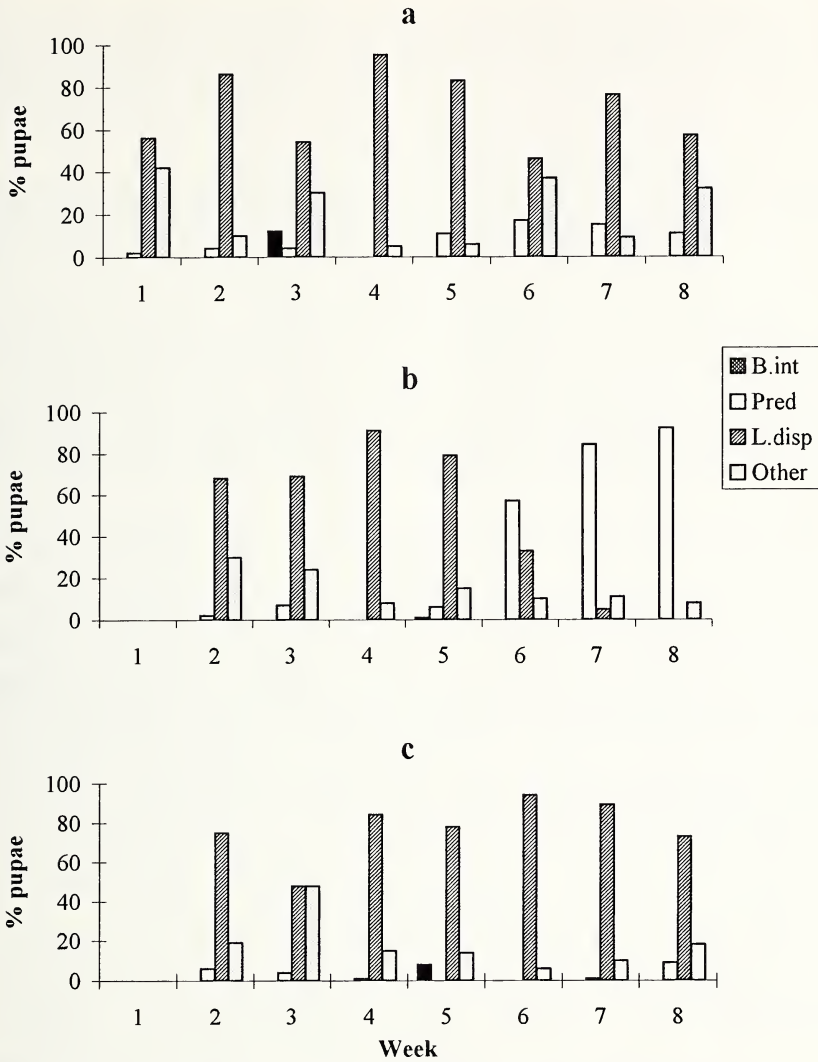
Fig. 1.   Fate of gypsy moth pupae exposed weekly in the field from June 2 to July 21, 1994 at three study sites (a- Ludlow, b- Amherst and c- Montague, MA) and subsequently reared in the laboratory. (B.int: emergence of *B. intermedia*, Pred: killed by predators, L.disp: moth emergence, Other: unexplained death. Weekly total of pupae equals 100.)

DISCUSSION

B. intermedia is a parasitoid with the most impact in high density gypsy moth populations. The incidence of parasitism has been correlated with egg mass counts, larval and pupal densities of gypsy moth, and percentage of defoliation (Reardon, 1976; Ticehurst et al., 1978; Williams et al., 1993). Although densities of gypsy

moths were fairly high at the study sites the preceding years, density of pupae was low at all sites in 1994 because larvae were decimated by an epizootic of nuclear polyhedrosis virus and fungal pathogen *Entomophaga maimaiga* Humber, Schimazu and Soper. Therefore, none of the sites was defoliated during this study and few field pupae were available for the wasps to parasitize. Coincidentally, the number of wasps recovered in our experiment was low at all three sites.

Considering the scarcity of pupae in the field, one might have expected that trap hosts would be particularly attractive to the wasps should they be present. If *B. intermedia* is monophagous on the gypsy moth, one might expect peak levels of parasitism to occur when the host population declines following an outbreak (delayed density dependence). However, Ticehurst et al. (1978) also observed a collapse of parasitism concurrent with the collapse of the host population. The low level of parasitism of trap hosts, suggests that either the small number of pupae was not sufficient to retain the wasps in the area, or that the wasps located sparsely distributed hosts with difficulty. Blumenthal et al. (1979) suggested that *B. intermedia* readily dispersed *en masse* from sparse infestation sites and colonized high density populations.

Although trap hosts were present in the field for eight or seven weeks, it is striking that wasps were recovered within a single week at each site. These hosts were parasitized approximately two weeks before peak pupation (gypsy moth development was almost two weeks advanced at Ludlow compared to the other two sites). Apparently, *B. intermedia* was present in the field for a limited period of time, somewhat synchronized with pupation of the gypsy moth. The sites of Amherst and Montague had been visited weekly from late spring to early summer to search for *B. intermedia*. The leaf litter, dead trees and crevices were examined within ca. 5,000 square meters around the study sites of Amherst and Montague as they might have sheltered aggregated overwintering wasps (Dowden, 1935; Waldvogel and Brown, 1978), but no wasps were located. This suggests that *B. intermedia* was not present on these sites early in the season and that the wasps arrived near the time of pupation of gypsy moth larvae. In the absence of sufficient numbers of pupae, *B. intermedia* might have emigrated elsewhere, as suggested by Blumenthal et al. (1979).

Even when wasps did parasitize trap hosts, only a small fraction was parasitized. While 12 pupae out of 100 were parasitized in Ludlow, 54 were evidently not, as adults emerged later. In Montague 8 pupae were parasitized and 78 were not. In Amherst one pupa was successfully parasitized and 79 were not. In addition, the pupae in a cage were never all parasitized. In Ludlow, 6 pupae were parasitized in two cages on neighboring trees. In Montague, the 8 parasitized pupae were found in 5 different cages. Female *B. intermedia* produce 5 offspring on average per day (Dowden, 1935; Barbosa et al., 1986), and can successfully parasitize up to 11 pupae in a row in the laboratory (Drost and Cardé, 1992b). Therefore, a single wasp potentially could parasitize most of the pupae in a cage on a single visit. However, previous direct observations of the behavior of *B. intermedia* in the field (in 1993 in Montague, unpublished data) revealed that the wasps almost always visited only one pupa within a cluster. The present results corroborate these findings.

Despite the small number of wasps recovered, our results indicate that the population of reproductively active *B. intermedia* was reasonably synchronized with the availability of gypsy moth pupae. Yet, the life history of *B. intermedia* in the field

remains equivocal as the apparent synchrony with the gypsy moth population may indicate that the wasps either use the gypsy moth as a unique host or parasitize alternate hosts in other habitats.

LITERATURE CITED

Barbosa, P., P. Martinat, and R. Bennet. 1986. Consequences of maternal age and host deprivation on the production and development of *Brachymeria intermedia* (Nees) and the mortality of its gypsy moth (*Lymantria dispar*) host. J. Appl. Entomol. 101:215–223.

Bell, R. A., C. D. Owens, M. Shapiro, and J. G. R. Tardif. 1981. Development of mass rearing technology. Pages 599–631 *in:* The gypsy moth: research toward integrated pest management. C. C. Doane and M. L. McManus (eds.)—USDA, Techn. Bull. 1584.

Blumenthal, E. M., R. A. Fusco, and R. C. Reardon. 1979. Augmentative release of two established parasite species to suppress populations of the gypsy moth. J. Econ. Entomol. 72:281–288.

Buonaccorsi, J. P. and J. S. Elkinton. 1990. Estimation of contemporaneous mortality factors. Res. Popul. Ecol. 32:151–171.

Clausen, C. P. 1978. Introduced parasites and predators of arthropod pests and weeds: a world review. USDA, Agr. Handbook. 480.

Dindo, M. L. 1990. Comportemento di oviposizione di *Brachymeria intermedia* (Nees) (Hym. Chalcididae) in crisalidi di *Galleria mellonella* L. (Lep. Galleriidae). Boll. Ist. Entomol. G. Grandi Univ. Bologna. 45:109–119.

Dowden, P. B. 1935. *Brachymeria intermedia* (Nees), a primary parasite and *B. compsilurae* (Cfwd.), a secondary parasite, of the gypsy moth. J. Agric. Res. 50:495–523.

Drost Y. C. and R. T. Cardé. 1992a. Host switching in *Brachymeria intermedia* (Hymenoptera: Chalcididae), a pupal endoparasitoid of *Lymantria dispar* (Lepidoptera: Lymantriidae). Environ. Entomol. 21:760–766.

Drost, Y. C. and R. T. Cardé. 1992b. Influence of host deprivation on egg load and oviposition behaviour of *Brachymeria intermedia,* a parasitoid of gypsy moth. Physiol. Entomol. 17: 230–234.

Elkinton, J. S., J. P. Buonaccorsi, T. S. Bellows, Jr., and R. G. Van Driesche. 1992. Marginal attack rate, *k*-values and density dependence in the analysis of contemporaneous mortality factors. Res. Popul. Ecol. 34:29–44.

Howard, L. O. and W. F. Fiske. 1911. The importation into the United States of the parasites of the gypsy moth and the brown-tail moth: A report of progress, with some considerations of previous and concurrent efforts of this kind. USDA Bur. Entomol. Bull. 91: 240–252.

Hoy, M. A. 1976. Establishment of gypsy moth parasitoids in North America: An evaluation of possible reasons for establishment or non-establishment. Pages 215–232 *in:* Perspectives in Forest Entomology. J. F. Anderson and H. K. Kaya (eds.). Academic Press Inc., New York.

Leonard, D. E. 1966. *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae) established in North America. Entomol. News. 77:25–27.

Leonard, D. E. 1975. Parasitization of the spruce budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae) by *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae). J. New York Entomol. Soc. 83:269–270.

Minot, M. C. and D. E. Leonard. 1976. Host preference and development of the parasitoid *Brachymeria intermedia* in *Lymantria dispar, Galleria mellonella, and Choristeoneura fumiferana.* Environ. Entomol. 5:527–532.

Prokopy, R. J. 1968. Parasites of the leaf rollers *Archips argyrospilus* and *A. griseus* in Connecticut. J. Econ. Entomol. 61:348–352.

Reardon, R. C. 1976. Parasite incidence and ecological relationships in field populations of gypsy moth larvae and pupae. Environ. Entomol. 5:981–987.

Rotheray, G. E., P. Barbosa, and P. Martinat. 1984. Host influences on life history traits and oviposition behavior of *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae). Environ. Entomol. 13:243–247.

Schaefer, P. W. 1993. Overwintering aggregations of female *Brachymeria intermedia* (Hymenoptera: Chalcididae). Entomol. News. 104:133–135.

Ticehurst, M., R. A. Fusco, R. P. Kling, and J. Unger. 1978. Observations on parasites of gypsy moth in first cycle infestations in Pennsylvania from 1974–1977. Environ. Entomol. 7: 355–358.

Van Driesche, R. G., T. S. Bellows, J. S. Elkinton, J. R. Gould, and D. N. Ferro. 1991. The meaning of percentage parasitism revisited: Solutions to the problem of accurately estimating total losses from parasitism. Environ. Entomol. 20:1–7.

Waldvogel, M. G. and M. W. Brown. 1978. An overwintering site of the gypsy moth parasite, *Brachymeria intermedia.* Environ. Entomol. 7:782.

Williams, D. W., R. W. Fuester, W. W. Metterhouse, R. J. Balaam, R. H. Bullock, R. J. Chianese, and R. C. Reardon. 1993. Incidence and ecological relationships of pupal parasitism by *Brachymeria intermedia* in New Jersey populations of the gypsy moth. Entomophaga. 38:257–266.